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Seattle City Light

Air Compressor Analysis Report

Prepared for

Ash Grove Cement Company
Seattle, Washington

Prepared by

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On behalf of

Energy Management Services Division
Seattle City Light
Seattle, Washington

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Contents

Preface

The recommendations presented in this report were prepared based on the data collected during a one-day site-visit and discussions with the plant personnel. Where data were not available, assumptions were made to estimate energy and dollar savings. The report provides a reasonable assessment of the compressed air usage in your plant and opportunities available to reduce costs by improving the performance of compressed air systems. However, Seattle City Light, its contractors and subcontractors do not guarantee the accuracy or completeness of the information presented. Further, Seattle City Light, its contractors, subcontractors, employees, agents and officers make no representation or warranty, whatsoever, expressed or implied, as to the fitness, design, performance or capability of the material, equipment or workmanship in any compressed air system, and are not liable for any and all damages resulting from the use of information provided in this report. It is recommended that further engineering analysis and design be performed and manufacturers consulted prior to implementing the recommendations contained in this report.

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Section 1 - Executive Summary

A review of your 110 psig air compressor system was done during a site visit on October 16, 1996 by Mr. William Scales, a nationally renowned air compressor expert, and representatives of Seattle City Light.

The recommendations shown in the Saving Summary Table below can reduce the annual electrical usage of the 110 psig system by about 47% of your annual compressor energy. Estimated annual savings from the five recommendations presented in this report are about $27,000 requiring a capital investment of just $25,000, yielding a simple payback period of less than one year.

The Savings Summary table presents the recommended Air Compressor Efficiency Improvement Measures (ACEIMs), which are fully described later in the report. The saving estimates are conservative because non-energy benefits such as reduced maintenance costs could not be fully estimated.

ACEIM Savings Summary										
	Demand Charge: $0.63 /kW-mo.		**Energy Charge:** $0.03130 /kWh							
ACEIM #	ACEIM Description	Peak Demand (kW)	Demand ($)	Energy (kWh)	Energy ($)	% Air Energy Use	Cost Savings	Implementation Cost	Payback Years
1	**Re-Automate Dust Collectors**	26.9	$204	201,105	$6,294	11.3%	$6,498	$3,000	0.5
2	**Replace Air Horns with Blower**	52.9	$394	162,243	$5,078	9.0%	$5,472	$6,000	1 4
3	**Reduce System Pressure**	19.0	$144	141,971	$4,444	7.9%	$4,588	$3,000	0.7
4	**Fix Air Leaks**	28.9	$219	216,692	$6,782	12.1%	$7,001	$1,000	0 1
5	**Use Refrigerated Air Dryer**	30.6	$116	114,525	$3,585	6.4%	$3,701	$12,000	3.2
*	**Maximum Savings**	158.3	$1,077	836,536	$26,183	46.6%	$27,260	$25,000	0.9

Note: The ACEIMs are presented in the recommended order of priority. Annual savings are incremental. If some of the higher priority ACEIMs are not implemented, the savings from lower priority measures would be somewhat higher than those shown in the table above. Demand saving for ACEIM 5 is based on six months. See ACEIM 5 for details.

As shown in the table above, the major opportunities available to reduce the operating cost of the 110 psig system are:

- reducing the pulsed jets of compressed air used by dust collectors by changing the process from a timed sequence to a demand cycle, based on the differential pressure across the bags;
- replacing the air horns with a low pressure eductor, which utilizes a blower;
- reducing the system pressure after replacing the existing air cylinders with larger diameter cylinders or installing an air pressure booster to supply high pressure air for multiple cylinders within a given area;
- fixing air leaks throughout the plant; and

- using a refrigerated air dryer instead of the regenerative dryer when a 40-45 degree pressure dewpoint is adequate.

The combination of the above ACEIMs should result in the plant being able to shut down one 200 HP compressor, and operate with one 200 HP compressor in conjunction with smaller compressors. In addition, integrating the operation of the 75 HP and two 30 HP rotary screw compressors with the main compressed air system would possibly result in a shut down of the 75 HP rotary screw compressor and reduced run-time of the 30 HP compressors. Further, by undertaking an extensive leak detection and repairs program, the plant will continue to benefit from reduced air compressor operating costs, which include lower electric bills and reduced maintenance costs.

Special mention should be made that Mike Ralls was an extremely cooperative and knowledgeable representative, and knew all the systems in great detail, which made a difficult one-day audit much easier.

The compressed air systems are in excellent condition in most ways. The next section of the report describes the plant air usage and assessment of the compressed air system. Air Compressor Efficiency Improvement Measures are described in detail in section 3. Other observations on your plant's compressed air system and operating practices are provided in section 4.

Section 2 - Introduction

Plant Operation

A review of the 110 psig air compressor system operating at Ash Grove Cement Company in Seattle was done during a site visit on October 16, 1996 by Mr. William Scales, a nationally renowned air compressor expert, representatives of Seattle City Light including: Jim Healy, Dave VanHolde, and Tim Newcomb, and Eric Bessey - a representative of Strategic Energy Technologies. The report is based on observations made by them during and after the site visit, and discussions with plant personnel, especially Mike Ralls.

Ash Grove Cement Company operates 5-7 days per week for 50 weeks per year or approximately 7,500 hours per year. Compressed air is supplied by the air compressors listed in the following table:

Compressor Summary						
	Compressor 1	Compressor 2	Compressor 3	Compressor 4	Compressor 5	Compressor 6
manufacturer	Quincy_Northwest	Quincy_Northwest	Quincy_Northwest	Quincy_Northwest	Quincy_Northwest	Quincy_Northwest
model	QNW740C	QNW740C	QNW740C	QNW360-D2	QNWF30N	QNWF30N
type	rotary screw	rotary screw	rotary screw	rotary screw	rotary screw	rotary screw
horsepower (hp)	200	200	200	75	30	30
capacity (acfm)	752	752	752	361	131	131
Control	Load-Unload	Load-Unload	Load-Unload	Load-Unload	Load-Unload	Load-Unload

Detailed compressor performance data are shown in Appendix A.

Air Compressor Operation

Ash Grove Cement Company has many compressed air systems. The low pressure Fuller compressors supply 35-40 psig compressed air for pneumatic conveying and certain other processes. Although several Fuller compressors may be running at any given time, these compressors do not operate continuously. The plant air system operates approximately 7,500 hours per year and is maintained at a nominal 110 psig pressure. During the site-visit, pressures of 114 psig were observed throughout the day.

The plant has undergone numerous modifications in the last five years with increasing centralization of the 110 psig system. Plant personnel indicated that the dust collectors, which are the major intermittent users of compressed air, require 75 psig to provide adequate compressed air pulses to keep the filter bags clean. Another application that uses large amounts of compressed air continuously is kiln cooling in which "air movers" (referred to as "air horns" because of their shape) or eductors, through the venturi principle, entrain atmospheric air using compressed ~~air. The~~ air is directed at the kiln to cool the shell. At least, one air horn is always in use, while the other two are sporadically operated. It was estimated that a second air mover would be operated approximately 30 percent of the time, and the third about 10 percent.

In addition, there are pneumatic cylinders, instrument systems, air tools and other devices used for various yard applications. Some of the air cylinders require 90 psig pressure to operate flop gates, which are used perhaps twelve times per day. These flop gates will not function properly at lower pressures.

Plant air is supplied by three (3) 750 cfm, 200 HP Quincy compressors, centrally operated by a sequencing control panel that monitors air pressure. Normal operation requires two air compressors to be running - one at full load and the second operating on line/off line, loading and unloading. For the plant operation observed during the site visit, it is estimated that the compressed air load was approximately 1200 cfm. The air is dried by a heatless twin tower regenerative dryer, which requires 239 cfm of continuous purge air for regenerating the desiccant.

Another air system uses a 75 HP Quincy rotary screw compressor which is dedicated to a water spray cooling operation, and was operating at 40% of its volumetric capacity. The (2) 30 HP air cooled compressors in a remote location are utilized for a 1200 bag dust collector system. These two air systems discussed above are isolated from the main plant and are not included in the analysis.

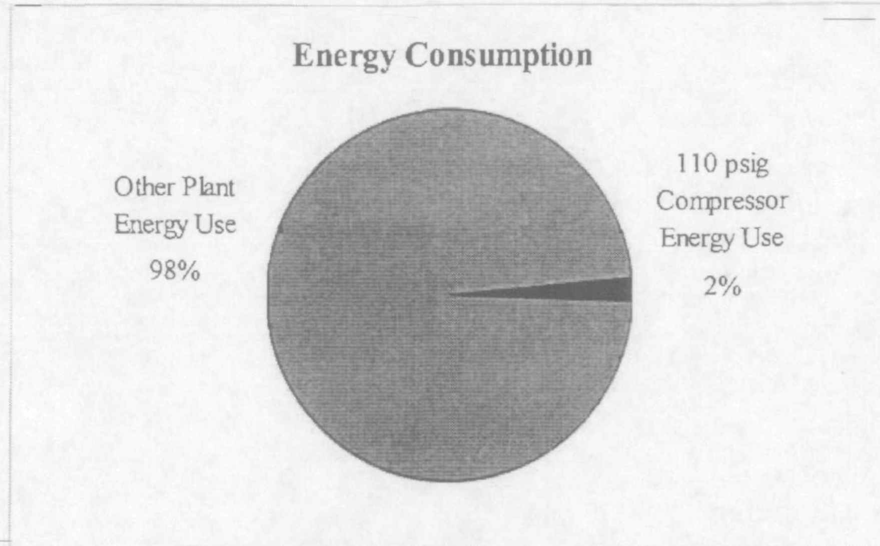
Assessment of Compressed Air Systems

The following table shows the evaluation of air compressor components and system. It highlights the observed condition of the compressed air system and operating practices.

Assessment of Compressed Air System			
	200 hp QNW Screws	**75 hp and 30 hp QNW Screws**	**System**
air intake -location -quality -air filter	-intakes located inside. -inside is dry and clean. -air filters in good cond.	-intakes located inside. -inside is dry and clean. -air filters in good cond.	
major components -compressor -motor -distribution pipe -air receivers	-motors and compressors in good cond.	-motors and compressors in good cond.	-distribution pipe in good cond. -sufficient air receiver capacity is present.
accessories -aftercoolers -oilcoolers -air dryers	-aftercoolers are in good working order. -condensate was noticed after the moisture separators, check auto. traps for proper operation.	-aftercoolers and oilcoolers are in good working order.	-excessive oil was found in the afterfilter of the regenerative dryer which adversely affects the desiccant.
miscellaneous -gauges -end use filters -valves -moisture separators	-gauges and valves appear to be in good working order.	-gauges and valves appear to be in good working order.	-gauges and valves appear to be in good working order.
controls -staging -unloading	-compressors operate in a load-unload mode.	-compressors are equipped with low-unload control; however, unloading point is set so high that compressors seldom unload.	-sequencer controls 200 hp compressors. -Compressors not in use are turned off.
safety			-no specific concerns.

Compressed Air Energy Use

We believe that the 110 psig compressed air system operates approximately 7,500 hours per year. The following chart shows that the 110 psig compressed air system uses about 2 percent of annual electric energy consumption (1,786,194 kWh per year or about $57,000 out of the total plant usage of 87,472,663 kWh). The plant air demand profile is shown in Appendix D.



In addition to accounting for a significant share of annual electrical energy consumption, compressed air systems warrant attention because compressed air they produce is the most inefficient utility in any plant. Compressed air systems typically convert only about 20% of the energy they use into useful work. Air compressor efficiency improvements can increase profits at relatively low cost; thus, providing high returns on investment.

For analyzing the compressed air system, compressor operation was modeled as 312 twenty-four hour days (yielding 7,488 annual hours). To model typical operation, two day types of six months (152 days) each were used to facilitate estimation of savings from using a refrigerated dryer when weather conditions permitted.

Section 3 - Air Compressor Efficiency Improvement Measures

3.1 Re-Automate Dust Collectors

Recommended Action

Reduce the pulsed jets of compressed air used to clean filter bags by changing the process automation from a timed sequence to a demand cycle, based on the differential pressure across the bags.

ACEIM Summary			
Energy Savings (kWh)	Total Dollar Savings	Implementation Cost	Payback (years)
201,105	$6,498	$3,000	0.5

Operating Conditions

The bag house dust collectors are the largest users of compressed air. The filter bags are cleaned by releasing pulsed jet of compressed air at regular intervals whether required or not. This practice results in higher consumption of compressed air because pulsed jets will operate even when the filter bags are clean. On the other hand, differential pressure sensors sense the pressure difference across the filter bags and release pulsed jets of compressed air only when the differential air pressure exceeds a pre-determined set point based on the amount of dirt deposit on filter bags.

If it is assumed that dust collectors use 600 cfm of compressed air, Mr. Ralls estimated a potential savings of thirty percent is achievable by switching over to differential pressure controls. This 180 cfm reduction in compressed air consumption reduces the power draw by 26.9 KW, saving 201,105 kWh annually

Implementation Plan

It is recommended that the automated timed sequence cycle should be changed to on-demand cycle that uses differential pressure controls. The annual cost savings are estimated at $6,499. The implementation cost is estimated at $3,000, resulting in a payback of less than six months.

The following table shows the existing and proposed conditions and savings summary. The existing conditions show the estimated air flow, power consumption, and operating hours under the current operating practice. Similar data are shown for

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the proposed conditions after the recommended ACEIM is implemented. The difference between the existing and proposed condition is shown as savings. Detailed explanation of the terms used is provided in Appendix E.

Table 3-1: Re-automate Dust Collectors

Existing Conditions					
Operating Conditions	Air Flow ($\%C_s$)	Power ($\%P_s$)	Power (kW)	Operation (hours)	Energy (kWh)
six months	55.5%	58.3%	238.5	3,744	893,097
six months	55 5%	58.3%	238.5	3,744	893,097
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		65.9%	269.5	7,488	1,786,194

Proposed Conditions					
Operating Conditions	Air Flow ($\%C_s$)	Power ($\%P_s$)	Power (kW)	Operation (hours)	Energy (kWh)
six months	47.5%	51.8%	211.7	3,744	792,544
six months	47.5%	51.8%	211.7	3,744	792,544
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		59.3%	242.6	7,488	1,585,089

Savings Summary						
Demand Charge:	$0.63 /kW-mo.		**Energy Charge:**		$0.03130 /kWh	
	Demand (kW)	Demand ($)	Operation (hours)	Energy (kWh)	Energy ($)	Cost Savings
six months			3,744	100,552	$3,147	$3,147
six months			3,744	100,552	$3,147	$3,147
			0	0	$0	$0
			0	0	$0	$0
Total	26.9	$204	7,488	201,105	$6,294	$6,498

3.2 Replace Air Horns with Blower

Recommended Action

Replace the air horns with a low pressure eductor, which utilizes a blower.

ACEIM Summary			
Energy Savings (kWh)	Total Dollar Savings	Implementation Cost	Payback (years)
162,243	$5,472	$6,000	1.1

note: This ACEIM assumes the previous ACEIM has been implemented.

Operating Conditions

The single, largest continuous users of air are "air movers" (referred to as "air horns" because of their shape). Each eductor, operating on the venturi principle to entrain atmospheric air, uses approximately 130 scfm of compressed air at 80 psig. This is directed at the kiln to cool the shell. At least, one air horn is always in use while the other two are sporadically operated. It was estimated that a second air mover would be operated approximately 30 percent of the time (on average 8 hours per day, 312 days per year), and the third about 10 percent (on average 2 hours per day, 312 days per year).

Expensive high pressure compressed air is not required for cooling, which can be provided by a 5 hp fan or blower, perhaps with a shroud, operating at a very low pressure.

Implementation Plan

Total annual electricity consumption from operating eductors is estimated at 205,760 kWh based on manufacturers' performance data at 80 psig. If the supplied pressure is greater, the electricity consumption will be higher. Assuming the same operating hours, three fans would consume 43,517 kWh annually, resulting in net annual saving of 162,243 kWh or $4,357.

The implementation cost for three blowers is estimated at $6,000 ($2,000 per blower), yielding a simple payback period of 1.4 years.

Note: Mike Ralls has ordered an axial fan, which will be tested, and the results reported.

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The following table[1] shows the existing and proposed conditions and savings summary. The existing conditions show the estimated air flow, power consumption, and operating hours under the current operating practice. Similar data are shown for the proposed conditions after the recommended ACEIM is implemented. The difference between the existing and proposed condition is shown as savings. Detailed explanation of the terms used is provided in Appendix E.

Table 3-2: Replace Air Horns with Blower

Existing Conditions					
Operating Conditions	Air Flow ($\%C_s$)	Power ($\%P_s$)	Power (kW)	Operation (hours)	Energy (kWh)
six months	47.5%	51.8%	211.7	3,744	792,544
six months	47.5%	51.8%	211.7	3,744	792,544
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		59.3%	242.6	7,488	1,585,089

Proposed Conditions					
Operating Conditions	Air Flow ($\%C_s$)	Power ($\%P_s$)	Power (kW)	Operation (hours)	Energy (kWh)
six months	39.3%	45.0%	184.2	3,744	689,664
six months	39.3%	45.0%	184.2	3,744	689,664
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		45.2%	184.8	7,488	1,379,329

Savings Summary						
Demand Charge:	$0.63 /kW-mo.		**Energy Charge:**		$0.03130 /kWh	
	Demand (kW)	Demand ($)	Operation (hours)	Energy (kWh)	Energy ($)	Cost Savings
six months			3,744	102,880	$3,220	$3,220
six months			3,744	102,880	$3,220	$3,220
			0	0	$0	$0
			0	0	$0	$0
Total	57.9	$439	7,488	205,760	$6,440	$6,879

[1] The proposed condition in the table shows the impact on compressed air energy consumption without the additional electrical energy usage of 5 hp fans.

3.3 Reduce System Pressure

Recommended Action

Reduce the system air pressure by ten psi after addressing the flop gates operation problem as recommended below.

ACEIM Summary			
Energy Savings (kWh)	Total Dollar Savings	Implementation Cost	Payback (years)
141,971	$4,588	$3,000	0.7

note: This ACEIM assumes the previous ACEIM has been implemented. Implementation cost is that of plan "a".

Operating Conditions

At present, flop gates are operated by pneumatic cylinders that require high air pressure (90 psig). It is expensive to produce compressed air at higher air pressures. Lowering the pressure by 10 psi will reduce input power by five percent, and air consumption by approximately seven percent. While it is advantageous to operate at the lowest possible air pressure, the flop gates must function properly which is possible by following one of the two recommendations described below. The impact of lowering set pressure on power consumption is shown Appendix F.

Implementation Plan

Address the air cylinder problem at the flop gates by either:

a. supplying a booster for multiple cylinders within a given area; or
b. installing larger diameter cylinders, which will apply greater force at a lower air pressure.

A booster will maintain the required pressure for flop gates while allowing a system wide reduction in the air pressure. Similarly, larger diameter cylinders will apply the same force at a lower air pressure to operate flop gates. By implementing either recommendation, the air pressure at the compressors and at the facility can be reduced by at least ten psi.

The purchase price of a booster package for the air cylinders is approximately $2,000, and the installation (no electrical connections necessary) cost is estimated at about $1,000 for a total installed cost of $3,000 for a booster package. An alternative to installing a booster is replacing air cylinders at an estimated cost of $600 per cylinder.

Estimated annual energy savings are 141,971 kWh or $4,588, yielding a simple payback period of 0.7 years.

The following table shows the existing and proposed conditions and savings summary. The existing conditions show the estimated air flow, power consumption, and operating hours under the current operating practice. Similar data are shown for the proposed conditions after the recommended ACEIM is implemented. The difference between the existing and proposed condition is shown as savings. Detailed explanation of the terms used is provided in Appendix E.

Table 3-3: Reduce System Pressure

Existing Conditions					
Operating Conditions	Air Flow ($\%C_s$)	Power ($\%P_s$)	Power (kW)	Operation (hours)	Energy (kWh)
six months	39.3%	47.4%	184.2	3,744	689,664
six months	39.3%	47.4%	184.2	3,744	689,664
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		47.6%	184.8	7,488	1,379,329

Proposed Conditions					
Operating Conditions	Air Flow ($\%C_s$)	Power ($\%P_s$)	Power (kW)	Operation (hours)	Energy (kWh)
six months	36.3%	42.5%	165.2	3,744	618,679
six months	36.3%	42.5%	165.2	3,744	618,679
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		42.7%	165.7	7,488	1,237,358

Savings Summary						
Demand Charge:	$0.63 /kW-mo.		**Energy Charge:**		$0.03130 /kWh	
	Demand (kW)	Demand ($)	Operation (hours)	Energy (kWh)	Energy ($)	Cost Savings
six months			3,744	70,985	$2,222	$2,222
six months			3,744	70,985	$2,222	$2,222
			0	0	$0	$0
			0	0	$0	$0
Total	19.0	$144	7,488	141,971	$4,444	$4,588

3.4 Fix Air Leaks

Recommended Action

Fix air leaks throughout the plant. Implementing this and the previous ACEIMs will allow one 200 hp QNW compressor to meet plant air needs.

ACEIM Summary			
Energy Savings (kWh)	Total Dollar Savings	Implementation Cost	Payback (years)
216,692	$7,001	$1,000	0.1

note: This ACEIM assumes the previous ACEIM has been implemented.

Operating Conditions

As is the case with most plants, air leaks at Ash Grove Cement are a major concern and waste energy. While it was not possible to perform a comprehensive leak survey, it was evident that compressed air was leaking at many locations throughout the facility. The following major leaks were found.

- Valve on the regenerative dryer 15 cfm
- Pressure reducing valve at a flop gate air cylinder at northwest corner 5 cfm

Plants similar to Ash Grove, where the distribution system is outdoors covering a large area, fifteen percent of the total supply is wasted by air leaks. Usually, at least fifty percent of these are easily repaired. This amounts to 90 cfm of *repairable* leaks (probable leakage rate is 180 cfm or 15% of 1200 cfm load) for which savings are estimated.

Implementation Plan

Repairing air leaks will save energy. In addition, if previously recommended ACEIMs are implemented, a 200 HP air compressor can be shut down. The plant will be able to operate with just one 200 HP compressor. Estimated annual energy savings from fixing air leaks and shutting down a 200 HP compressor are 216,692 kWh or $7,002. The repair cost is estimated at less than $1,000, yielding a simple payback of less than two months.

The following table shows the existing and proposed conditions and savings summary. The existing conditions show the estimated air flow, power consumption, and operating hours under the current operating practice. Similar data are shown for the proposed conditions after the recommended ACEIM is implemented. The

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difference between the existing and proposed condition is shown as savings. Detailed explanation of the terms used is provided in Appendix E

Table 3-2: Repair Air Leaks

Existing Conditions					
Operating Conditions	Air Flow (%C_s)	Power (%P_s)	Power (kW)	Operation (hours)	Energy (kWh)
six months	36.3%	40.4%	165.2	3,744	618,679
six months	36.3%	40.4%	165.2	3,744	618,679
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		40.5%	165.7	7,488	1,237,358

Proposed Conditions					
Operating Conditions	Air Flow (%C_s)	Power (%P_s)	Power (kW)	Operation (hours)	Energy (kWh)
six months	32.3%	33.3%	136.3	3,744	510,333
six months	32.3%	33.3%	136.3	3,744	510,333
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		33.5%	136.8	7,488	1,020,666

Savings Summary						
Demand Charge:	$0.63 /kW-mo.		**Energy Charge:**		$0.03130 /kWh	
	Demand (kW)	Demand ($)	Operation (hours)	Energy (kWh)	Energy ($)	Cost Savings
six months			3,744	108,346	$3,391	$3,391
six months			3,744	108,346	$3,391	$3,391
			0	0	$0	$0
			0	0	$0	$0
Total	28.9	$219	7,488	216,692	$6,782	$7,002

3.5 Use Refrigerated Air Dryer

Recommended Action

During the seasons, when a 40-45 degree pressure dewpoint is adequate, use a refrigerated air dryer, instead of the existing regenerative dryer.

ACEIM Summary			
Energy Savings (kWh)	Total Dollar Savings	Implementation Cost	Payback (years)
114,525	$3,701	$12,000	3.2

note: This ACEIM assumes the previous ACEIM has been implemented.

Operating Conditions

The existing regenerative dryer produces compressed air with a -40^0 F dew point which may not be needed during warmer months. Since the regenerative dryer uses 239 cfm purge air to regenerate the desiccant, using a refrigerated dryer would eliminate this usage for six months a year or more when the temperatures do not fall below freezing.

Annual electricity usage due to the existing purge rate is 137,025 kWh. A refrigerated air dryer would consume approximately 6 kW for these six months (3,744 hours), increasing electrical energy consumption by about 22,500 kWh, resulting in a net savings of 114,525 kWh.

Implementation Plan

Replace the regenerative dryer with a refrigerated air dryer for the period when temperatures do not fall below freezing. Annual dollar savings are estimated at $3,701. The installed cost of a refrigerated dryer is estimated at $12,000, yielding a simple payback of 3.2 years.

The following table[2] shows the existing and proposed conditions and savings summary. Two day types were selected: six months representing a period when the desiccant dryer is necessary, and six months representing a period when a refrigerative dryer may be used. The existing conditions show the estimated air flow, power consumption, and operating hours under the current operating practice. Similar data are shown for the proposed conditions after the recommended ACEIM is

[2] The proposed condition in the table shows the impact on compressed air energy consumption without the additional electrical energy usage of a refrigerated dryer.

implemented. The difference between the existing and proposed condition is shown as savings. Detailed explanation of the terms used is provided in Appendix E.

Table 3-5: Use Refrigerated Air Dryer

Existing Conditions					
Operating Conditions	Air Flow (%Cs)	Power (%Ps)	Power (kW)	Operation (hours)	Energy (kWh)
six months	32.3%	33.3%	136.3	3,744	510,333
six months	32.3%	33.3%	136.3	3,744	510,333
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		33.5%	136.8	7,488	1,020,666

Proposed Conditions					
Operating Conditions	Air Flow (%Cs)	Power (%Ps)	Power (kW)	Operation (hours)	Energy (kWh)
six months	32.3%	33.3%	136.3	3,744	510,333
six months	21.7%	24.4%	99.7	3,744	373,308
	0.0%	0.0%	0.0	0	0
	0.0%	0.0%	0.0	0	0
Total		33.5%	136.8	7,488	883,641

Savings Summary						
Demand Charge:	$0.63 /kW-mo.		**Energy Charge:**		$0.03130 /kWh	
	Demand (kW)	Demand ($)	Operation (hours)	Energy (kWh)	Energy ($)	Cost Savings
six months			3,744	0	$0	$0
six months			3,744	137,025	$4,289	$4,289
			0	0	$0	$0
			0	0	$0	$0
Total	30.6	$116	7,488	137,025	$4,289	$4,405

Section 4 - Other Observations

1. The afterfilter at the regenerative dryer has a significant quantity of oil in it. There should be no oil in this filter. Oil adversely affects the desiccant. Check the prefilter to be certain it is in good condition. Contaminated desiccant should be replaced even though it is expensive to do so.

2. Use electric vibrators where practical, instead of air vibrators.

3. Check the integral automatic drain trap inside the moisture separators downstream of the aftercoolers on each 200 HP compressor. There was evidence of condensate after the separators (usually indicates a malfunctioning drain trap).

4. Three (3) belt driven blowers appear to normally supply excess capacity, and blowing off the excess air through pressure relief valves. Reduce the motor pulley size ten percent to reduce input horsepower. These blowers and Fuller sliding vane compressors are process related, and it does not appear that other cost savings recommendations would be economically justified, considering the possible impact on production.

The plant has a 75 HP rotary screw compressor, which supplies compressed air to water-air injectors, in a hot gas stream for cooling purposes. This was operating at 40% of capacity or approximately 140 cfm, but consuming approximately 60 BHP. This compressed air load can be added to the main air supply, and the 75 HP compressor shut down. It should then be operated with the existing control panel, only as needed

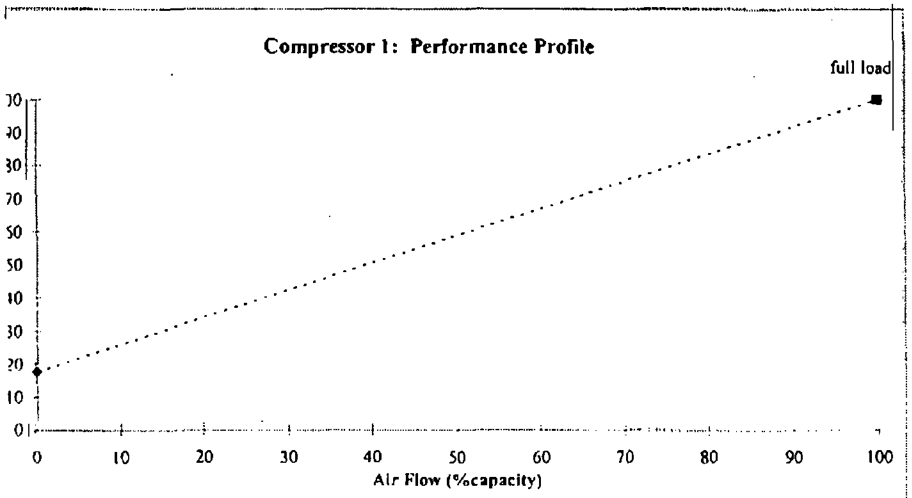
Similarly, two (2) 30 HP rotary screw compressors can be automated, so that they are part of the main system, and operated only when system pressure drops to a critical point. Presently, these compressors are dedicated to a specific bag house dust collector. While there are savings in energy associated with these measures, they have not been included, as some increase will be reflected in the 200 HP compressor operation. However, maintenance costs will definitely be reduced and the system reliability will increase because of these new found "spares".

Appendix A - Compressor Inventory and Performance

The following table and graphs give detailed information on the compressors at Ash Grove Cement Company. Compressor 1 is one of the 200 hp Quincy Northwest compressor. Compressors 2 and 3 are identical to compressor 1. Compressor 4 is the 75 hp Quincy Northwest and compressor 5 is one of the 30 hp Quincy Northwest compressors. Compressor 6 is identical to compressor 5. Since compressor performance wasn't actually measured, Measured Performance values are identical to Manufacturer's Performance values.

	Control Strategy		Inlet Conditions	
Quincy_Northwest			temperature (not used)	85 °F
QNW740C	unloading controls?	yes	elevation	0 ft.
rotary screw	unload type	load-unload		
181 bhp	unload point	100 %C		
752 acfm	automatic shutdown timer?	yes		
	automatic sequencer?	yes		

		Manufacturer's Performance			Measured Performance		
200 hp							
460 volts	full load power (kW)	139.9 kW	100.0 %P	0.88 s.f.	139.9 kW	100.0 %P	0.88 s.f.
223 amps	no load power (fully modulated)	95.1 kW	68.0 %P		95.1 kW	68.0 %P	
1800 rpm	no load power (unloaded)	24.7 kW	17.7 %P		24.7 kW	17.7 %P	
no	unload pt. power (kW)	139.9 kW	100.0 %P		139.9 kW	100.0 %P	100.0 %C
94.1 %	full load discharge pressure	125 psig			120 psig		
89.5 %	pressure range (PMIN to PMAX)	6 psi			15 psi		



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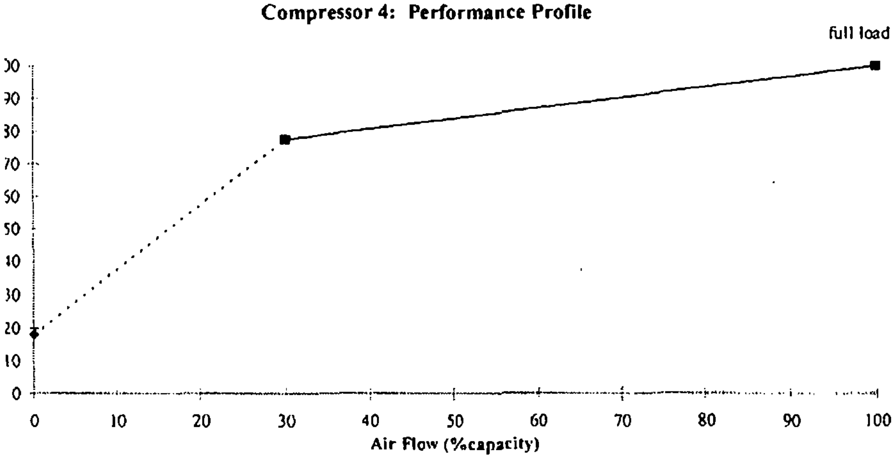
	Control Strategy		Inlet Conditions	
Quincy_Northwest			temperature (not used)	85 °F
QNW360-1	unloading controls?	yes	elevation	0 ft.
rotary screw	unload type	low-unload		
76 bhp	unload point	30 %C		
361 acfm	automatic shutdown timer?	no		
	automatic sequencer?	yes		

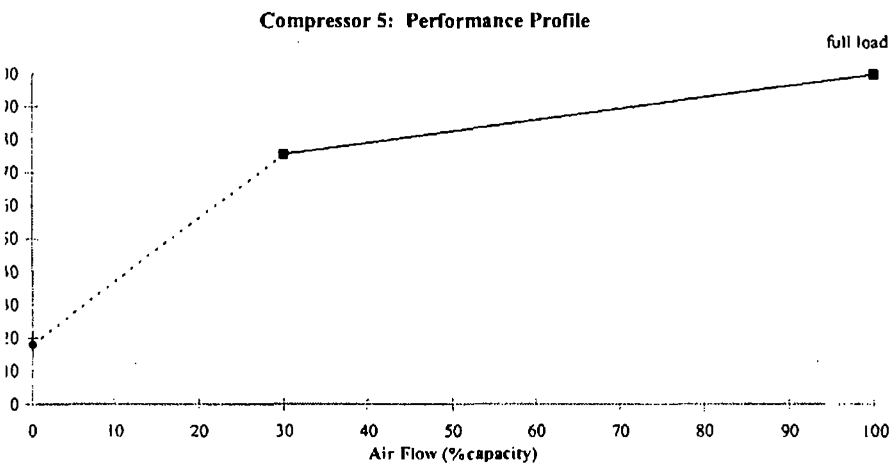
		Manufacturer's Performance			Measured Performance		
75 hp							
460 volts	full load power (kW)	61.8 kW	100.0 %P	1.01 s.f.	61.8 kW	100.0 %P	1.01 s.f.
96 amps	no load power (fully modulated)	42.0 kW	68.0 %P		42.0 kW	68.0 %P	
1800 rpm	no load power (unloaded)	11.1 kW	17.9 %P		11.1 kW	17.9 %P	
no	unload pt. power (kW)	48.0 kW	77.6 %P		48.0 kW	77.6 %P	30.0 %C
91.7 %	full load discharge pressure	100 psig			100 psig		
83.5 %	pressure range (PMIN to PMAX)	6 psi			6 psi		

Compressor 4: Performance Profile



	Control Strategy		Inlet Conditions	
Quincy_Northwest			temperature (not used)	85 °F
QNWF30A	unloading controls?	yes	elevation	0 ft.
rotary screw	unload type	low-unload		
33 bhp	unload point	30 %C		
131 acfm	automatic shutdown timer?	no		
	automatic sequencer?	yes		

		Manufacturer's Performance			Measured Performance		
30 hp							
460 volts	full load power (kW)	27.1 kW	100.0 %P	1.10 s.f.	27.1 kW	100.0 %P	1.10 s.f.
37 amps	no load power (fully modulated)	17.6 kW	65.0 %P		17.6 kW	65.0 %P	
1800 rpm	no load power (unloaded)	4.9 kW	17.9 %P		4.9 kW	17.9 %P	
no	unload pt. power (kW)	20.4 kW	75.5 %P		20.4 kW	75.5 %P	30.0 %C
91 %	full load discharge pressure	100 psig			100 psig		
83 %	pressure range (PMIN to PMAX)	6 psi			6 psi		



Appendix B - Assumptions

Annual operating hours are approximately 7,500 for the compressed air system.

Motor efficiency of 0.93 at full load for the 200 hp compressor.
Motor efficiency of 0.917 at full load for the 75 hp compressors.
Motor efficiency of 0.91 at full load for the 30 hp compressors.

*Average Energy Charge:	$0.0313 per kWh
*Average Demand Charge:	$0.632 per kW-month

* *Average energy and demand charges were calculated using billing from August 1995 through September 1996.*

Appendix C - Air Leak Table

Plant Area	ID # /name			Pressure (Psig)		Air Leak	
		Qty.	Description	Actual	Req'd	Leak	Description
main comp. rm	N/A	1				15 cfm	valve on regen. dryer
tower 6	N/A	2				10 cfm	press. red. valve on flop gate

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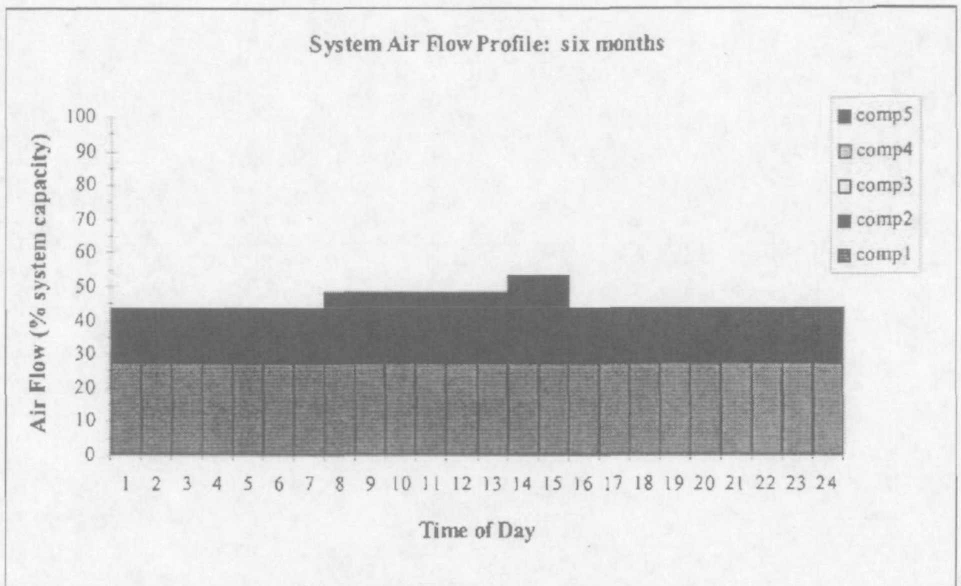
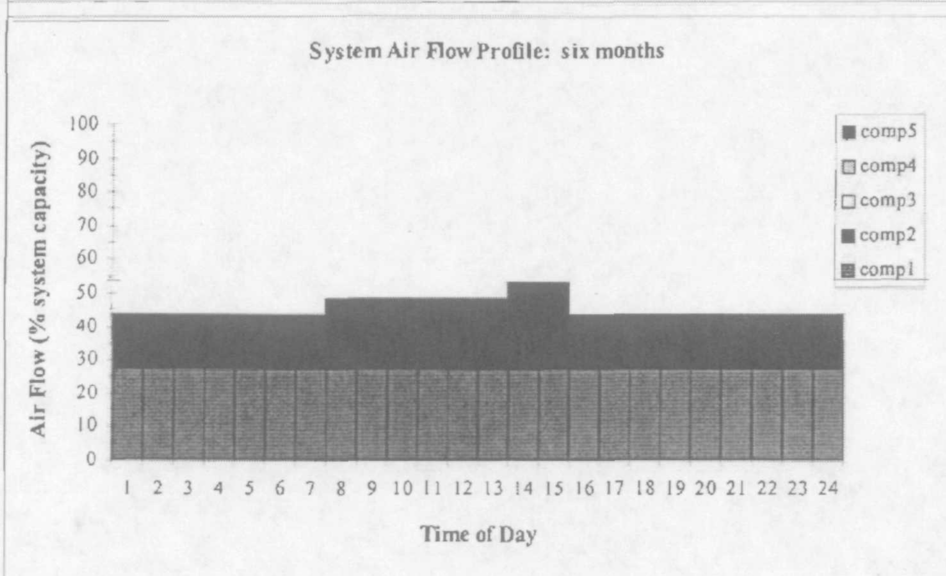
Appendix D - Plant Air Flow Profiles

The system air flow profiles shown below reflect the main plant (200 hp) system only. 75 hp and 30 hp compressor systems are not included.





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Appendix E - Explanation of Technical Terms

Existing and proposed operating conditions are included in the summary tables under Operating Conditions of each ACEIM. Air flow and power are averaged by day-type over the hours in which at least one compressor is turned on. For example, if compressors are turned on eight hours in a day, then air flow and power is averaged only over the operating eight hours. Totals for operating hours and energy are provided and are the sums of all day-types. Total power is the peak hourly demand found in all day-types. Existing peak demand does not necessarily occur during the same day-type as the proposed peak demand.

Savings are calculated as the difference between existing and proposed conditions for each day-type, and are included in the Savings Summary. Energy, demand, and cost savings (energy plus demand savings) are calculated based on utility rate schedules. Totals for operating hours and energy are provided and are the sums of all day-types. Total demand is the difference between existing and proposed peak demands.

Nomenclature

$\%C$	=	Percentage of compressor capacity at any load.
$\%C_s$	=	Percentage of system capacity at any load.
$\%P$	=	Percentage of full load power at any load.
$\%P_s$	=	Percentage of system full load power at any load.

Appendix F - Power Draw at Reduced Air Pressure